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TEST RESULTS OF PHASE 2 LEVEL A SUITS TO CHALLENGE BY CHEMICAL AND BIOLOGICAL WARFARE AGENTS AND SIMULANTS EXECUTIVE SUMMARY

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Swatches from six commercially available Level A protective suits were challenged with liquid droplets of sarin (GB) and mustard (HD) using modifications of the static diffusion procedure described in TOP 8-2-501. The cumulative mass of each agent that permeated each swatch was determined over time, and the results for all swatches were used to determine a weighted-average cumulative mass for each suit. From these data, a breakthrough time was calculated for each suit for comparison purposes. In addition, intact suits were challenged with corn-oil aerosol to simulate a biological aerosol. Protection factors were determined for each suit.

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EXECUTIVE SUMMARY

As part of the Domestic Preparedness Program, six Occupational Safety and Health Level A* suit designs were tested to assess their capability to protect in a chemical warfare (CW) agent or biological agent environment. Swatches of material from each suit design were tested for resistance to permeation for Sarin (GB) and mustard (HD). From this data, the authors calculated the estimated time it would take to permeate the suit with sufficient agent to cause physiological effects in a person wearing the suit. Each suit design was also tested for its protection factor in an aerosol environment (aerosolized corn oil, which may be representative of a chemical or biological agent, was used). Protection factor is defined as the ratio between the challenge concentration outside the suit and the measured concentration inside the suit. The tests are described, and the calculated breakthrough times and overall protection factors are presented.

*Level A protection consists of a completely encapsulating, gas/vapor proof chemical-resistant suit; a self-contained breathing apparatus (SCBA) or positive-pressure supplied-air respirator with escape SCBA, chemical-resistant gloves and boots.

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PREFACE

The work described in this report was authorized under the Expert Assistance (Equipment Test) Program for the U.S. Army Soldier and Biological Chemical Command (SBCCOM) Program Director for Domestic Preparedness. This work was started in January 1999 and completed in September 1999.

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TEST RESULTS OF PHASE 2 LEVEL A SUITS TO CHALLENGE BY CHEMICAL AND BIOLOGICAL WARFARE AGENTS AND SIMULANTS EXECUTIVE SUMMARY

1. INTRODUCTION

In 1996, responding to Public Law 104 – 201(Defense Against Weapons of Mass Destruction Act of 1996), the Department of Defense (DoD) formed the Domestic Preparedness Program. One of the objectives was to enhance federal, state, and local emergency and hazardous material (HAZMAT) response to nuclear, biological and chemical (NBC) terrorism incidents. In some cases, Occupational Safety and Health Administration (OSHA) Level A protective suits may be required to enter a contaminated or potentially contaminated area. Limited data was available concerning the effectiveness of commercially available and commonly used OSHA Level A suits as protection against chemical warfare (CW) agents. Recognizing this need, the U.S. Army Soldier and Biological Chemical Command (SBCCOM) established a program to test some of the Level A suit designs, using CW agents and test procedures developed for assessment of military-issue CW protective equipment. A detailed technical report was generated for each suit design tested, and a summary report was prepared that presented the essential results for all the suits in a single document. Because those reports are rather lengthy and technical, this report was prepared. This report is an overview of the results of the evaluation and is intended primarily for federal, state and local emergency and HAZMAT personnel as an aid in their evaluation (and possible modification) of current work rules regarding specific Level A suits currently in inventory and as an aid in future procurement of appropriate Level A suits.

The suits and suit materials were tested in new, as-received condition. The effects of aging, temperature extremes, laundering, and other factors were beyond the scope of this test program. Level A suits are totally encapsulated suits that protect the wearer from liquid, vapor, and gaseous chemicals and particulates. Air is supplied by a pressure-demand full-facepiece self-contained breathing apparatus (SCBA) or supplied air lines. These tests addressed percutaneous (i.e. skin) protection only and not the air supply system.

Each suit was tested in two different ways, the measurement of permeation of both GB and HD through material swatches and measurement of the total aerosol leakage into the suits when worn as part of a complete personal protective equipment (PPE) system under simulated conditions. In the permeation tests, sample swatches were cut from selected areas (the basic suit material, a suit seam, and four other areas that were dependent upon the suit configuration) of each suit design. These swatches were then exposed to the chemical agents Mustard (HD) and Sarin (GB), and the vapor permeation of agent through them measured. Sarin is a non-persistent (volatile) nerve agent, and HD is a persistent blister agent. In the aerosol tests, each suit design was donned by volunteer testers, who carried out a prescribed sequence of movements inside a test chamber containing a controlled aerosol of corn oil that is a non-toxic simulant for chemical and biological agent aerosols. Instrumentation continuously measured the concentration of simulant inside the suit. Each of these tests examined different aspects of the protection provided by the suits.

2. LIQUID CHALLENGE/VAPOR PENETRATION TEST (SWATCH TEST)

For each suit design under test, six swatches (three to be tested with GB and three with HD) were taken from each of six different areas of the suit – 36 total swatches per suit design. The swatches were placed in a test fixture and a predetermined (10 g/m^2) liquid agent challenge, GB or HD, was applied to the top surface of each swatch, and the fixture sealed. Periodically, over 24 hr, gas samples were taken from below the swatches. The amount of agent vapor that permeated the test swatch at each sampling time was measured using a highly sensitive, accurate, miniaturized gas chromatograph and sampling system known as MINICAMS™ (OI Analytical, CMS Field Products Group, Birmingham, AL).

The cumulative mass of agent, which has permeated each of the swatches at each sampling time, divided by the area of the swatch, is defined as the permeation, M_f.

The permeation for each area of the suit tested was compared with other areas and other suit designs. Normally, continuous exposure to chemical agent would not exceed 8 hr (480 min) because of heat stress and fatigue, so the permeation, which occurs in the subsequent 16 hr, is of less interest.

Weighted average M_f values were calculated for each suit design. As an example, the equation for the Trellchem TBE was:

Weighted average M_f = 0.5(suit material M_f) + 0.15(suit seam material M_f) + 0.15(visor material M_f) + 0.1(boot seam M_f) + 0.05(suit/visor interface M_f) + 0.05(zipper/material interface M_f)

Mustard vapor can produce skin irritation (erythema) at dosages (product of concentration and exposure time) of approximately 100 $mg\text{-}min/m^3$. Sarin vapor can produce incapacitation at dosages of approximately 8000 $mg\text{-}min/m^3$. Skin permeabilities were estimated to be 2 cm/min for HD and 0.1 cm/min for GB. Breakthrough M_f values were then calculated as reported by Lindsay[1]. The equation was:

Breakthrough M_f (ng/cm^2) = Skin permeability, P_s (cm/min) x Breakthrough Dosage ($mg\text{-}min/m^3$).

The calculated breakthrough times from all the suit swatches are collected and presented in Table 1.

[1]Lindsay, R.S., *Test Results of Phase 2 Level A Suits to Challenge by Chemical and Biological Warfare Agents and Simulants: Summary Report*, ECBC-TR-187, U. S. Army Edgewood Chemical Biological Center, Aberdeen Proving Ground, MD, June 2001, UNCLASSIFIED Report.

Table 1. Swatch Test Results for Level A Suits

Item	Breakthrough time, minutes	
	GB	HD
Kappler Responder Plus 43580	84	249
Kappler Lifeguard Responder 41550	196	175
Kappler Responder/NFPA Ensemble 41560	408	237
Trelleborg Trellchem VPS Suit	>1440	257
Trelleborg Trellchem TSE Suit	300	250
Trelleborg Trellchem TBE Suit	70	81

3. SYSTEM TEST (AEROSOL SIMULANT)

This test measures the leakage of corn-oil aerosol (physical simulant for biological aerosols) into a suit ensemble. In this test, a volunteer donned an ensemble of a suit design (using a SCBA). The volunteer then entered the test chamber that contained a controlled concentration of aerosolized corn oil. The volunteer performed prescribed exercises in the test chamber, while low-volume air samples were taken from within the suit at the neck and upper arm and the corn-oil concentrations recorded continuously.

Eight different suits of each design were available in a range of sizes to fit the volunteers who participated in the test. A total of at least 22 test runs using at least 10 different testers, were completed for each suit design. During the test run, the volunteer performed each of the 8 pre-operational exercises for 1 min and each of the 8 operational exercises for 4 min. See Table 2. The total exposure/exercise time for each complete test run was therefore 40 min ((8 x 1) + (8 x 4) = 40).

Table 2. Aerosol Test Exercise Routine

Phase of Test	Description of Exercise
Phase 1 (Pre-Operational) – Each exercise performed for 1 min.	1) Standing still, normal breathing
	2) Bending forward and touching toes
	3) Jogging in place
	4) Raising arms above head and looking upward
	5) Bending knees and squatting
	6) Crawling on hands and knees
	7) Torso twists with hands folded on chest
	8) Standing still, normal breathing
Phase 2 (Operational) – Each exercise performed for 4 min.	1) Climb step ladder
	2) Move 3-lb boxes from table to floor
	3) Rest
	4) Roll walls and ceiling with paint roller
	5) Bag clothes
	6) Rest
	7) Loosen bolts
	8) Move 3-lb boxes from floor to table

The corn-oil concentration measurements from within the suit, along with the known concentration of corn-oil aerosol in the test chamber, is used to calculate the protection

factor (PF) of the suit ensemble for the test conditions. Essentially, PF is a measure of the reduction in cumulative exposure to the aerosol afforded by the suit. A higher percentage of suits that pass at higher PFs means better protection.

The PF for an ensemble design is affected by the fit of the suit, the design of its seals and closures, and the amount of air exhaled by the wearer during the test. The results for a given suit design often vary widely from one test run to the next. The calculated values of PF for each suit design are compared to some PF values (100, 1000, 2000) to make the distribution of results more apparent. Also, because the PF is often affected greatly by the volunteer's movements, the two parts of each test run are analyzed and presented separately. These data were compiled and summarized for all the actual suit designs in Table 3.

Table 3. Summary of Overall Aerosol Test Results

Item	Percentage of Test Runs Where PF Met Each Hypothetical PF Threshold Value					
	100		1000		2000	
	Pre-Operational	Operational	Pre-Operational	Operational	Pre-Operational	Operational
Kappler Responder Plus 43580	100	100	65.2	89.1	47.8	73.9
Kappler Lifeguard Responder 41550	100	100	66.7	72.9	29.2	45.8
Kappler Responder/NFPA Ensemble 41560	100	100	72.2	68	48.2	52
Trelleborg Trellchem VPS Suit	100	100	100	95.4	91.7	95.4
Trelleborg Trellchem TSE Suit	100	100	100	97.9	95.8	97.9
Trelleborg Trellchem TBE Suit	100	97.9	100	97.9	95.8	97.9

4. CONCLUSIONS AND RECOMMENDATIONS

The test data reveals that the OSHA Level A suits tested can protect the wearers from CW agents. The duration of protection provided by each suit design will vary considerably according to how well the suit is fitted to the individual, the body motions required, and the concentration and distribution of the chemical agent in the environment.

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